PATENT ABSTRACTS OF JAPAN

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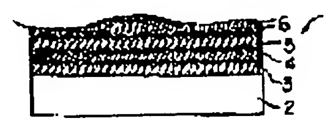
(21)Application number : 07-347668
(22)Date of filing : 15.12.1995
(71)Applicant : SANO FUJI KOKI KK
(72)Inventor : KAWAMURA NOBUJI

(54) DOUBLE REFRACTIVE FILM AND OPTICAL SYSTEM USING THE SAME

(57)Abstract:
PROBLEM TO BE SOLVED: To make it possible to enhance the degree of freedom in designing an optical system when a double refractive film formed with diagonally vapor deposited films by alternately laminating diagonally vapor deposited single layer films consisting of dielectric materials different from each other in the diagonally vapor deposited film is used for the optical system.



SOLUTION: The double refractive plate 1 is constituted by alternately forming the single layer films 3, 5 consisting of TiO2 (titanium dioxide) and the single layer films 4, 6 consisting of SiO2 (silicon oxide) by diagonal vapor deposition on a transparent glass substrate 2. The respective single layer films 3, 4, 5, 6, are set at approximately ?/4 (?=650nm) in the films thickness. The double refractive plate 1 is formed by a vapor deposition apparatus. In such a case the TiO2 and SiO2 are used as the dielectric materials. Any dielectric materials which are basically transparent to the light to be used and with which the desired double refraction quantity is obtainable by the combinations of the materials are usable as the dielectric materials. For example, metal oxides, such as Ta2O5, Al2O3, WO3, Y2O3, Bi2O3, Nb2O5, ZnS, MoO3, etc., are usable.

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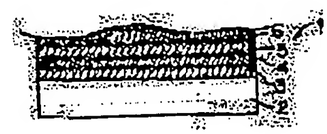

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CLAIMS

[Claim(s)]
[Claim 1] It is the birefringent plate which carries out the laminating of the slanting vacuum evaporationo monolayer which consists of dielectric materials from which this slanting vacuum evaporationo film differs mutually in the birefringent plate which carries out the vacuum evaporationo of the dielectric materials from across, and comes to form a slanting vacuum evaporationo film on the front face of a vacuum evaporationo-ed substrate by turns, and is characterized by the bird clapper.

[Claim 2] The birefringent plate according to claim 1 characterized by making into the abbreviation same direction the optical axis of all the slanting vacuum evaporationo monolayers that constitute the aforementioned slanting vacuum evaporationo film.
[Claim 3] Optical system using the birefringent plate which arranges a birefringent plate and is characterized by the bird clapper so that it may have the predetermined amount of birefringences and the plane of incidence and the aforementioned optical axis of a light beam which carry out incidence to this birefringent plate may serve as a predetermined angular relation-ship, after the light beam irradiated by this birefringent plate is injected from this birefringent plate in the optical system using the birefringent plate of a claim 2.

[Translation done.]

* NOTICES *

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1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[The technical field to which invention belongs] this invention relates to the birefringent plate in which the slanting vacuum evaporationo film used for various optical instruments was formed, and the optical system using this birefringent plate.
[0002]
[Description of the Prior Art] Conventionally, the birefringent plate in which the slanting vacuum evaporationo film of dielectric materials was formed on the substrate front face is known. By making a substrate front face incline to the coming-flying direction of vacuum evaporationo material (dielectric materials), arranging, and forming a vacuum evaporationo film as a columnar structure which grows in the direction of slant from a substrate front face, this makes the birefringence operation to an incident light give this vacuum evaporationo film, for example, is used for it as optical functional devices, such as a polarization beam splitter and a phase plate.
[0003]
[Problem(s) to be Solved by the Invention] By the way, in the **** birefringent plate mentioned above, it was difficult to control the phase contrast between the rectangular polarization components of the light which carries out incidence to this birefringent plate free. When following, for example, using the above-mentioned birefringent plate as a phase plate, it was difficult to acquire arbitrary phase contrast. Moreover, when using the above-mentioned birefringent plate as a beam splitter of a tabular, since the amount of birefringences was small, it was difficult [it] to design so that incidence of the light beam may be carried out with a small incident angle.
[0004] this invention is made in view of such a situation, and when using the birefringent plate in which it comes to form a slanting vacuum evaporationo film as various optical elements in an optical system, it aims at offering the optical system using the birefringent plate and this which can raise the flexibility of a design of the optical system.
[0005]
[Means for Solving the Problem] The birefringent plate of this invention carries out the vacuum evaporationo of the dielectric materials from across on the front face of a vacuum evaporationo-ed substrate, and in the birefringent plate which comes to form a slanting vacuum evaporationo film, this slanting vacuum evaporationo film carries out the laminating of the slanting vacuum evaporationo monolayer which consists of mutually different dielectric materials by turns, and is characterized by the bird clapper. Moreover, it is desirable to make into the abbreviation same direction the optical axis of all the slanting vacuum evaporationo monolayers that constitute the aforementioned slanting vacuum evaporationo film.
[0006] Furthermore, the optical system using the birefringent plate of this invention So that the optical axis of all the slanting vacuum evaporationo monolayers that constitute the aforementioned slanting vacuum evaporationo film is the above-mentioned birefringent plate made into the abbreviation same direction, and it may have the predetermined amount of birefringences, after the light beam irradiated by this birefringent plate is injected from this birefringent plate A birefringent plate is arranged and it is characterized by the bird clapper so that the plane of incidence and the aforementioned optical axis of a light beam which carry out incidence to this birefringent plate may serve as a predetermined angular relation-ship. In addition, the above "alternation" shall mean two kinds of not only monolayers but the state of accumulating three or more kinds of monolayers in order.
[0007]
[Embodiments of the Invention] Hereafter, it explains, referring to a drawing about 1 operation form of this invention. Drawing 1 is the schematic diagram showing the birefringent plate of 1 operation form of this invention. In addition, in drawing 1 , the scale of the direction of a laminating is drawn on a different scale from an actual scale. This birefringent plate 1 comes to form the monolayers 3 and 5 of TiO2 (titanium dioxide), and the monolayers 4 and 6 of SiO2 (silicon oxide) by slanting vacuum evaporationo by turns on the transparent glass substrate 2. In addition, it is possible to use the substrate which replaces with this transparent glass substrate and consists of various material.
[0008] Although omitted and drawn in drawing 1 , the laminating of a large number, for example, the monolayer of 22 layers, is carried out in fact. Moreover, the thickness of each monolayers 3, 4, 5, and 6 is set as abbreviation lambda / 4 (lambda= 650nm). The birefringent plate 1 shown in this drawing 1 is formed by the **** vacuum evaporationo equipment shown in drawing 2 (A).
[0009] The bell jar 11 exhausted by the vacuum in the interior with the exhaust air pump which does not illustrate this vacuum evaporationo equipment, The evaporation source 12 for evaporating the vacuum evaporationo material 12A and 12B of TiO2 and SiO2, The electron gun 13 which injects electron beam 13A for heating each vacuum evaporationo material 12A and 12B of this evaporation source 12, It has the dome-like work 15 grade which carries out setting maintenance of two or more substrates 16 at the predetermined angular position so that the vacuum evaporationo style 14 which evaporated from the evaporation source 12 may carry out incidence aslant to the front face of a substrate 16. Rotation of this dome-like work 15 is enabled at predetermined speed in the predetermined direction by the rotary motor which is not illustrated, and equalization of thickness is attained between the substrates 16 held by this and on each substrate 16. In

addition, the evaporation source 12 is arranged near the axis-of-rotation lower part of this dome-like work 15.
[0010] Moreover, drawing 2 (B) is drawing which looked at the dome-like work 15 of drawing 2 (A) from the upper part. Each substrate 16 is attached in the wall section of a dome by the predetermined substrate electrode holder which is not illustrated. In addition, in this view, although a part of substrate 16 held is drawn, in fact, in the direction of a perimeter enclosure, many substrates 16 are arranged, and it is made and held from a center position. moreover, although especially the incident angle alpha to substrate 16 front face of the above-mentioned vacuum evaporationo style 14 (angle; which the normal of a substrate 16 and the perpendicular direction make in practice -- below the same) is not limited, it is possible to prevent nebula-ization of a vacuum evaporationo film, making 45 degrees - about 65 degrees, then the amount of birefringences (difference deltan of the refractive index no to Tsunemitsu, and the refractive index ne to unusual light) into a large value by the average ...
[0011] In addition, although TiO_2 and SiO_2 are used as dielectric materials with the above-mentioned operation gestalt As dielectric materials used by this invention, are transparent to the light used fundamentally. And the metallic oxide of Ta_2O_5, aluminum2O3, WO_3, Y_2O_3, Bi_2O_3, Nb_2O_5, ZnS, MoO_3, CeO_2 and SiO, and SnO_2 grade can be used that the desired amount of birefringences should just be obtained with the combination of the material. Moreover, it is desirable to consider as the thickness which is the grade a columnar structure can fully grow up to be about each class, although it is possible for it not to be restricted to the thing of the above-mentioned example as thickness of a vacuum evaporationo film, and to consider as various thickness, for example, it is dozens of nm. Considering as the above is desirable.
[0012] Moreover, it is also possible for three or more kinds of monolayers to be repeated in order, and to be made to carry out a laminating. moreover, an optical axis [in / each vacuum evaporationo films 3, 4, 5, and 6 / on one birefringent plate 16 and] -- an abbreviation arranging **** cage -- In case this birefringent plate 16 is used, by adjusting appropriately the direction of this optical axis, the angular relation-ship of optical plane of incidence, and the value of an incident angle theta It is possible to obtain the optical system which can be made into the value of a request of the phase contrast between the polarization components with which can obtain desired polarization permeability and a polarization reflection factor, and components and an incident light cross at right angles.
[0013]
[Example] Hereafter, a concrete example is explained.
[0014] The incident angle alpha to the substrate 16 of the <example 1> vacuum evaporationo style 14 was set as 60 degrees, and thickness carried out the 22-layer laminating of the mutual layer of TiO_2 and SiO_2 set as lambda/4 (lambda= 650nm) on the transparent glass substrate 2 to the light, and formed the polarization beam splitter 20. Next, to the membrane formation front face of this polarization beam splitter 20, incidence of the light beam was carried out so that the degree theta of incident angle of a light beam might become 45 degrees, and so that optical plane of incidence and an optical axis might become parallel (drawing 3 (A)). In addition, the right figure of drawing 3 (A) is a side elevation when seeing from [in the left figure of drawing 3 (A)] arrow A. The light transmittance Tp of P component at this time, and light transmittance Ts of S component The spectral characteristic is shown in drawing 3 (B).
[0015] To the membrane formation front face of the polarization beam splitter 20 formed like the <example 2> above-mentioned example 1, incidence of the light beam was carried out so that the degree theta of incident angle of a light beam might become 45 degrees, and so that optical plane of incidence and an optical axis might intersect perpendicularly (drawing 4 (A)). In addition, the right figure of drawing 4 (A) is a side elevation when seeing from [in the left figure of drawing 4 (A)] arrow A. The light transmittance Tp of P component at this time, and light transmittance Ts of S component The spectral characteristic is shown in drawing 4 (B).
[0016] To the membrane formation front face of the polarization beam splitter 20 formed like the <example 3> above-mentioned example 1, incidence of the light beam was carried out so that the degree theta of incident angle of a light beam might become 0 degree (drawing 5 (A)). In addition, the right figure of drawing 5 (A) is a side elevation when seeing from [in the left figure of drawing 5 (A)] arrow A. The spectral characteristic of the polarization permeability To in the direction of Tsunemitsu at this time and the polarization permeability Te in the direction of unusual light is shown in drawing 5 (B). Moreover, the value of reflective phase deltao in the direction of Tsunemitsu at this time and reflective phase deltae in the direction of unusual light is shown in drawing 6 (B). in addition, the optical-element arrangement shown in drawing 6 (A), and To and Te of drawing 6 (B) The optical-element arrangement which shows the graph which shows the spectral characteristic to each drawing 5 (A), and To and Te of drawing 5 (B) the graph which shows the spectral characteristic -- substantial -- abbreviation -- it is the same Moreover, drawing 7 is a graph which shows the wavelength dependency of the two above-mentioned differences, reflective phase deltao and deltae.
[0017] The incident angle alpha to the substrate 16 of the <example of comparison> vacuum evaporationo style 14 was set as 0 degree, the 22-layer laminating of the mutual layer of TiO_2 and SiO_2 in which thickness was set as lambda/4 (lambda= 650nm) was carried out on the transparent glass substrate 2 to the light, and beam-splitter 20A which does not have form birefringence was formed. To the membrane formation front face of this beam-splitter 20A, incidence of the light beam was carried out so that the degree theta of incident angle of a light beam might become 45 degrees (drawing 8 (A)). In addition, the right figure of drawing 8 (A) is a side elevation when seeing from [in the left figure of drawing 8 (A)] arrow A. The light transmittance Tp of P component at this time, and light transmittance Ts of S component The spectral characteristic is shown in drawing 8 (B).
[0018] They are Tp and Ts so that clearly also from the graph which shows those spectral characteristics for the thing of the above-mentioned example 1 and an example 2 compared with the thing of the example of comparison. The interval of standup wavelength is narrow. Moreover, since it does not have a polarization property when it considers as the incident angle of theta= 0 degree, it is clear that the things of an example 3 differ greatly compared with this what does not have form birefringence.
[0019] In addition, it sets to drawing 6 and drawing 7 , and they are reflective phase deltao and deltae. Although the related numeric value is shown, it is possible (refer to drawing 10) for the phase of transparency to be shown similarly, of course, and, thereby, the flexibility of a design of optical system becomes large. Furthermore, when an incident angle theta becomes

except 0 degree, optical system can be designed, also taking phase deltap of P component, and phase deltas of S component into consideration.
[0020] The incident angle alpha to the substrate 16 of the <example 4> vacuum evaporationo style 14 is set as 60 degrees. Thickness the mutual layer of TiO2 (amount deltan=of birefringences 0.075), and Ta 2O5 (amount deltan=of birefringences 0.065) set up as shown in the following table 1 To the light, the 35-layer laminating was carried out on the transparent glass substrate 2, the best layer which consists of SiO2 (amount deltan**of birefringences 0) to which thickness was further set as shown in the following table 1 was formed, and phase plate 20B was produced. all the thickness at this time -- 2.064nm it was . It arranges, as this phase plate 20B is shown in drawing 9 (A), and wavelength lambdao is 600nm. Incidence of the light beam was carried out so that an incident angle theta might become 0 degree to the membrane formation front face of this phase plate 20B about a light beam (drawing 9 (A)). In addition, the right figure of drawing 9 (A) is a side elevation when seeing from [in the left figure of drawing 9 (A)] arrow A.
[0021] Phase plate 20B arranged by such state is wavelength lambdao. 600nm 88 degrees of phases of the polarization component which intersects perpendicularly can be mutually shifted to a light beam, and it functions as lambda/4 board. The spectral characteristic of the polarization permeability To in the direction of Tsunemitsu at this time and the polarization permeability Te in the direction of unusual light is shown in drawing 9 (B). Moreover, transparency phase deltao in the direction of Tsunemitsu at this time Transparency phase deltae in the direction of unusual light The graph showing the wavelength dependency of a difference is shown in drawing 10 . The concrete film composition of this example is shown in the following table 1.
[0022]
[Table 1]

膜No.	材料	屈折率no	膜厚d (nm)	4nod/λo
	空気	1.0		
1	SiO_2	1.46	89.5	1.045
2	TiO_2	2.3	39.5	0.727
3	Ta_2O_5	2.0	50.0	0.800
4	TiO_2	2.3	48.9	0.900
5	Ta_2O_5	2.0	62.5	1.000
6	TiO_2	2.3	54.3	1.000
7	Ta_2O_5	2.0	62.5	1.000
8	TiO_2	2.3	54.3	1.000
9	Ta_2O_5	2.0	62.5	1.000
10	TiO_2	2.3	54.3	1.000
11	Ta_2O_5	2.0	62.5	1.000
12	TiO_2	2.3	54.3	1.000
13	Ta_2O_5	2.0	62.5	1.000
14	TiO_2	2.3	54.3	1.000
15	Ta_2O_5	2.0	62.5	1.000
16	TiO_2	2.3	54.3	1.000
17	Ta_2O_5	2.0	62.5	1.000
18	TiO_2	2.3	54.3	1.000
19	Ta_2O_5	2.0	62.5	1.000
20	TiO_2	2.3	54.3	1.000
21	Ta_2O_5	2.0	62.5	1.000
22	TiO_2	2.3	54.3	1.000
23	Ta_2O_5	2.0	62.5	1.000
24	TiO_2	2.3	54.3	1.000
25	Ta_2O_5	2.0	62.5	1.000
26	TiO_2	2.3	54.3	1.000
27	Ta_2O_5	2.0	62.5	1.000
28	TiO_2	2.3	54.3	1.000
29	Ta_2O_5	2.0	62.5	1.000
30	TiO_2	2.3	54.3	1.000
31	Ta_2O_5	2.0	62.5	1.000
32	TiO_2	2.3	54.3	1.000
33	Ta_2O_5	2.0	62.5	1.000
34	TiO_2	2.3	48.9	0.900
35	Ta_2O_5	2.0	50.0	0.800
36	TiO_2	2.3	39.5	0.727
全膜厚			約2064	
	ガラス基板 (BK7)	1.51		

但し、λo=500nm

[0023]
[Effect of the Invention] As explained above, according to the birefringent plate of this invention, and the optical system using this, the slanting vacuum evaporationo of two or more kinds of monolayers is carried out by turns, and the slanting vacuum evaporationo film is formed. Therefore, by making into a parameter the dielectric materials, the optical thickness of each monolayer, and the number of layers which form each monolayer, since the thing of the desired amount of birefringences can be obtained, the design flexibility of an optical element can be raised. Moreover, in case every ********** and this optical element are used for the direction of the optical axis of each monolayer, the design flexibility of optical ****, as a result an optical system can be further raised by choosing appropriately the angular relation-ship of a direction and optical plane of incidence and the degree of incident angle of this optical axis.

[0024] For example, in the conventional polarization beam splitter, although the beam splitter of a tabular could not be used but the glass-block type beam splitter had to be used when a light beam carried out incidence with a small incident angle, it becomes possible by applying the thing of this invention to separate certainly 2 polarization components which intersect perpendicularly by the beam splitter of a tabular also to the light beam of a small incident angle. Moreover, since it can also

consider as the design which gives the function as a phase plate to this beam splitter, in a beam splitter, the phase plate (for example, lambda/4 board, lambda/2 board) which might be formed on one optical path of the latter part becomes unnecessary conventionally.
[0025] Moreover, in case the polarization component which supported each sexual desire news with the dichroic prism of an electrochromatic display video projector is compounded, [for example,] Since it started by the spectral characteristic of each [these] polarization component and the big gap has arisen in the value of wavelength, although the spectral characteristi~~c after composition will be stair-like in the~~ conventional thing Since the value of the wavelength of the standup in the spectral characteristic of the two above-mentioned polarization components can be set as a very near value by applying this invention, when these two polarization components are compounded, it is possible to prevent that the synthetic spectral characteristic becomes stair-like. In addition, it is also possible to change the spectral characteristic of another side and to extend both interval, without changing one spectral characteristic between the two above-mentioned polarization components.

[Translation done.]

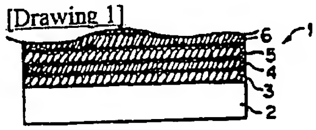
DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] The schematic diagram showing the lamination of the birefringent plate concerning the operation gestalt of this invention
[Drawing 2] The schematic diagram showing an example of the vacuum evaporationo equipment which forms the slanting vacuum evaporationo film of a birefringent plate shown in drawing 1
[Drawing 3] The graph which shows the optical-element plot plan (A) and light-transmittance property of an example 1 (B)
[Drawing 4] The graph which shows the optical-element plot plan (A) and light-transmittance property of an example 2 (B)
[Drawing 5] The graph which shows the optical-element plot plan (A) and light-transmittance property of an example 3 (B)
[Drawing 6] The graph which shows the optical-element plot plan (A), and a light-transmittance property and a reflective phase of an example 3 (B)
[Drawing 7] The graph which shows the difference of the reflective phase in an example 3
[Drawing 8] The graph which shows the optical-element plot plan (A) and light-transmittance property of the example of comparison (B)
[Drawing 9] The graph which shows the optical-element plot plan (A) and light-transmittance property of an example 4 (B)
[Drawing 10] The graph which shows the difference of the transparency phase in an example 4
[Description of Notations]
1 Birefringent Plate
2 Transparent Glass Substrate
3, 4, 5, 6 Monolayer
11 Bell Jar
12 Evaporation Source
12A, 12B Vacuum evaporationo material
13 Electron Gun
13A Electron beam
14 Vacuum Evaporationo Style
15 Dome-like Work
16 Substrate
20 20A Beam splitter
20B Phase plate

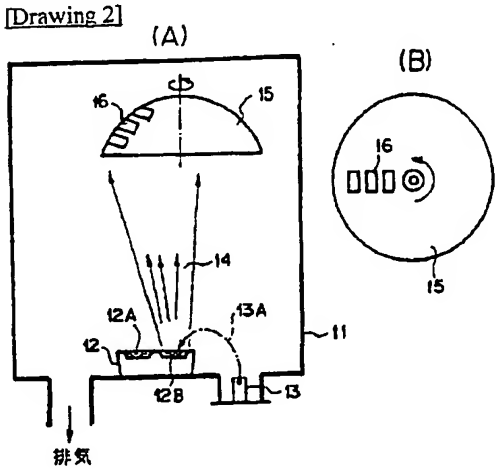
[Translation done.]

DRAWINGS

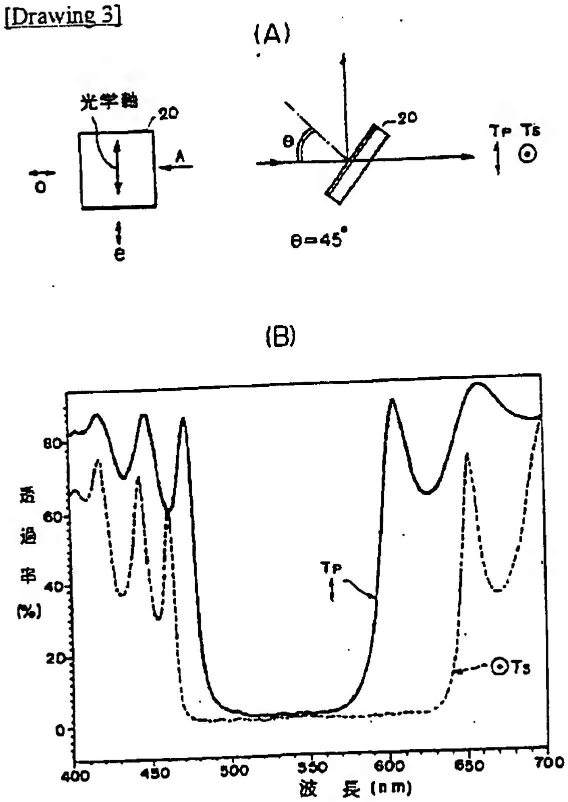
[Drawing 1]



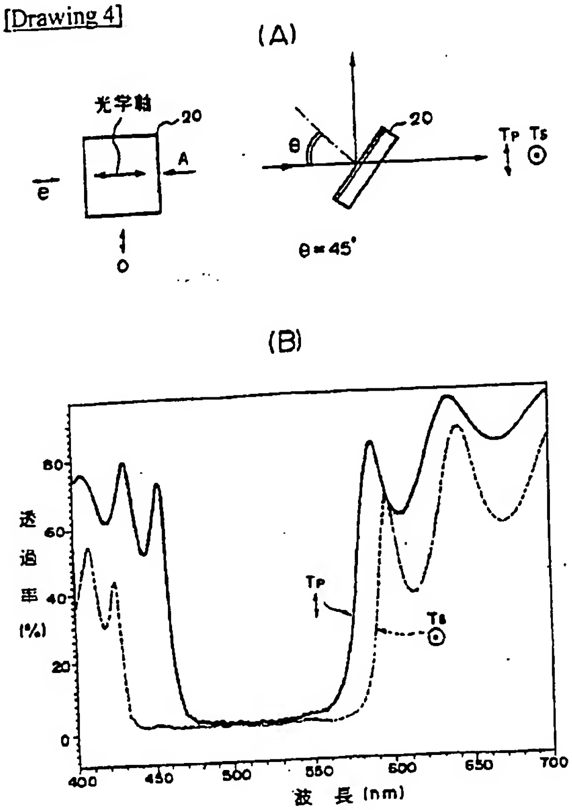
[Drawing 2]



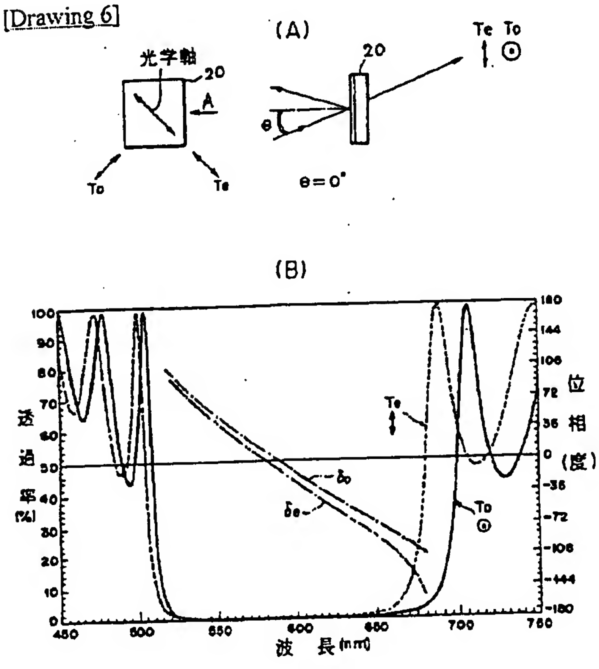
[Drawing 3]



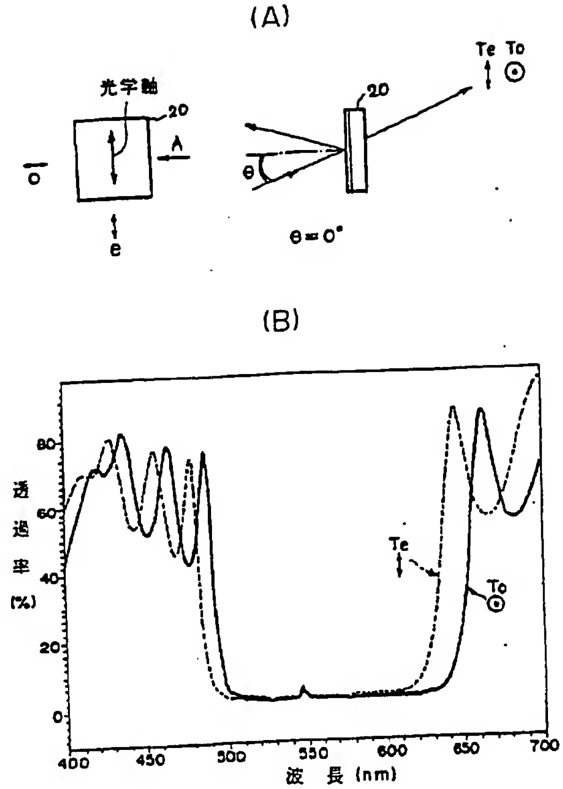
[Drawing 4]



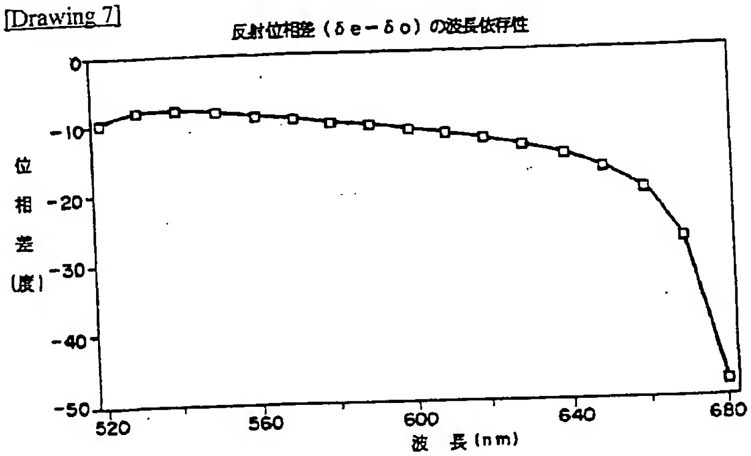
[Drawing 6]



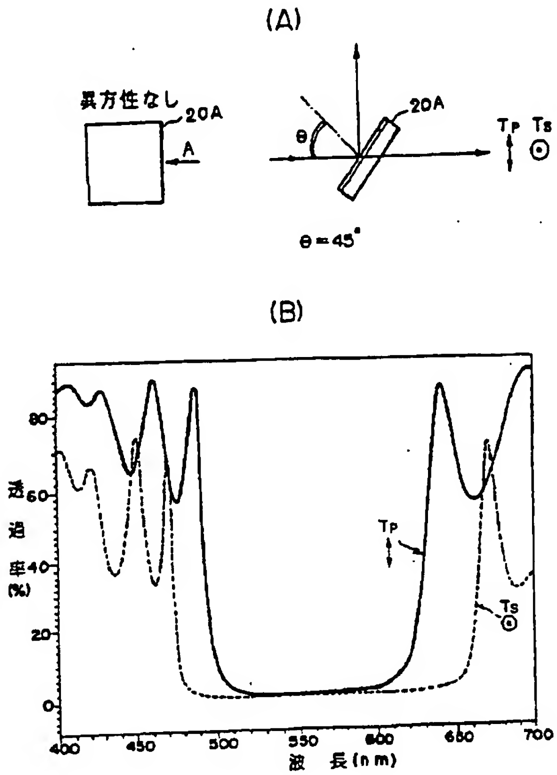
[Drawing 5]



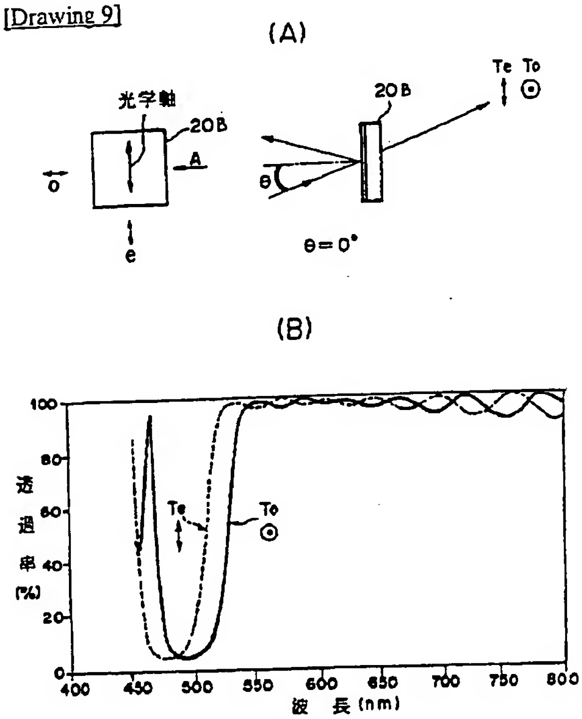
[Drawing 7]



[Drawing 8]

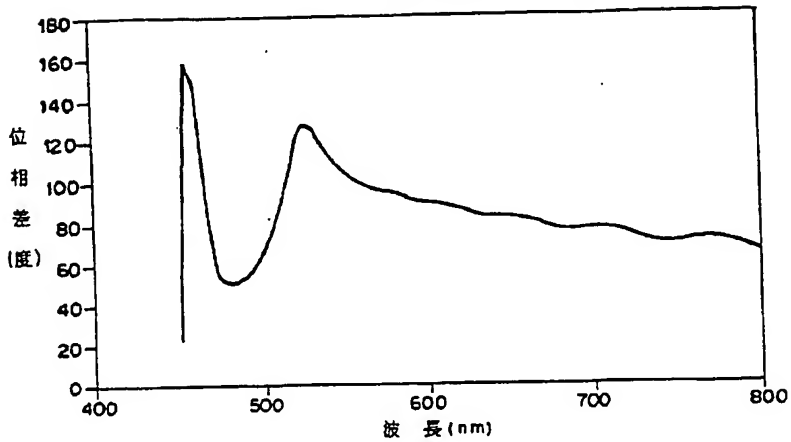


[Drawing 9]



[Drawing 10]

透過位相差（δo−δe）の波長依存性



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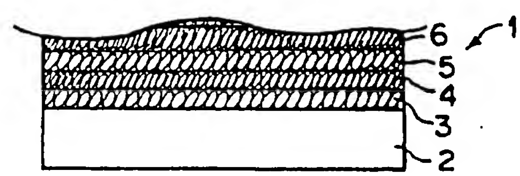
(54)【発明の名称】　複屈折板およびこれを用いた光学系

(57)【要約】

【目的】　互いに異なる所定の複数の誘電体材料からなる斜め蒸着単層膜を交互に積層してなる斜め蒸着膜により複屈折性を持たせ、各種光学要素として用いる場合にその光学設計の自由度を高める。

【構成】　この複屈折板１は、透明ガラス基板２上にＴｉO_2（二酸化チタン）の単層膜３，５とＳｉO_2（酸化ケイ素）の単層膜４，６を交互に斜め蒸着により形成してなる。図１には、省略して描かれているが、実際には２２層の単層膜が積層されている。また、各単層膜３、４、５、６の膜厚は略λ／4（λ=650nm）に設定されている。



【特許請求の範囲】
【請求項1】被蒸着基板の表面上に斜め方向から誘電体材料を蒸着せしめて斜め蒸着膜を形成してなる複屈折板において、
該斜め蒸着膜は、互いに異なる誘電体材料からなる斜め蒸着単層膜を交互に積層してなることを特徴とする複屈折板。
【請求項2】前記斜め蒸着膜を構成する全ての斜め蒸着単層膜の光学軸が略同一方向とされていることを特徴とする請求項1記載の複屈折板。
【請求項3】請求項2の複屈折板を用いた光学系において、
該複屈折板に照射された光ビームがこの複屈折板から射出された後に所定の複屈折量を有するように、この複屈折板に入射する光ビームの入射面と前記光学軸とが所定の角度関係となるよう複屈折板を配設してなることを特徴とする複屈折板を用いた光学系。
【発明の詳細な説明】
【0001】
【発明の属する技術分野】本発明は、各種光学機器に用いられる、斜め蒸着膜が形成された複屈折板およびこの複屈折板を用いた光学系に関するものである。
【0002】
【従来の技術】従来より、基板表面に誘電体材料の斜め蒸着膜を形成した複屈折板が知られている。これは、蒸着材料（誘電体材料）の飛来方向に対して基板表面を傾斜させて配置し、基板表面から斜め方向に成長する柱状組織として蒸着膜を形成することにより、該蒸着膜に、入射光に対する複屈折作用を付与せしめたものであり、例えば、偏光ビームスプリッタや位相板等の光学機能素子として利用されている。
【0003】
【発明が解決しようとする課題】ところで、上述した如き複屈折板においては、この複屈折板に入射する光の直交偏光成分間の位相差を自在に制御することが困難であった。したがって、例えば上記複屈折板を位相板として用いる場合には任意の位相差を得ることが難しかった。また、上記複屈折板を板状のビームスプリッタとして用いる場合には、複屈折量が小さいために小さい入射角で光ビームを入射させるように設計することは困難であった。
【0004】本発明はこのような事情に鑑みなされたものであり、斜め蒸着膜が形成されてなる複屈折板を光学システム中で各種光学要素として用いる場合に、その光学システムの設計の自由度を高めることができる複屈折板およびこれを用いた光学系を提供することを目的とするものである。
【0005】
【課題を解決するための手段】本発明の複屈折板は、被蒸着基板の表面上に斜め方向から誘電体材料を蒸着せしめて斜め蒸着膜を形成してなる複屈折板において、該斜め蒸着膜は、互いに異なる誘電体材料からなる斜め蒸着単層膜を交互に積層してなることを特徴とするものである。また、前記斜め蒸着膜を構成する全ての斜め蒸着単層膜の光学軸が略同一方向とされていることが望ましい。
【0006】さらに、本発明の複屈折板を用いた光学系は、前記斜め蒸着膜を構成する全ての斜め蒸着単層膜の光学軸が略同一方向とされている上記複屈折板であって、該複屈折板に照射された光ビームがこの複屈折板から射出された後に所定の複屈折量を有するように、この複屈折板に入射する光ビームの入射面と前記光学軸とが所定の角度関係となるよう複屈折板を配設してなることを特徴とするものである。なお、上記「交互」とは2種類の単層膜のみならず3種類以上の単層膜を順に積み重ねていく状態をも意味するものとする。
【0007】
【発明の実施の形態】以下、本発明の一実施形態について図面を参照しながら説明する。図1は、本発明の一実施形態の複屈折板を示す概略図である。なお、図1において、積層方向のスケールは実際のスケールとは異なるスケールで描かれている。　この複屈折板1は、透明ガラス基板2上にTiO_2（二酸化チタン）の単層膜3、5とSiO_2（酸化ケイ素）の単層膜4、6を交互に斜め蒸着により形成してなる。なお、この透明ガラス基板に代えて種々の材料よりなる基板を用いることが可能である。
【0008】図1では、省略して描かれているが、実際には多数の、例えば22層の単層膜が積層されている。また、各単層膜3、4、5、6の膜厚は略λ／4（λ=650nm）に設定されている。この図1に示す複屈折板1は例えば図2（A）に示す如き蒸着装置により形成される。
【0009】この蒸着装置は、図示しない排気ポンプにより内部を真空に排気されるベルジャー11と、TiO_2とSiO_2の蒸着材料12A、12Bを蒸発させるための蒸発源12と、この蒸発源12の各蒸着材料12A，12Bを加熱するための電子ビーム13Aを射出する電子銃13と、蒸発源12から蒸発した蒸着流14が基板16の表面に対し斜めに入射するように複数の基板16を所定の角度位置に設定保持するドーム状ワーク15等を備えている。このドーム状ワーク15は、図示されない回転モータにより所定方向に所定速度で回転可能とされており、これにより保持された基板16間および各基板16上において膜厚の均一化が図られる。なお、蒸発源12はこのドーム状ワーク15の回転軸下方の近傍に配設されている。
【0010】また、図2（B）は、図2（A）のドーム状ワーク15を上方から見た図である。各基板16は図示されない所定の基板ホルダによってドームの内壁部に

取り付けられる。なお、本図においては、保持される基板16の一部のみが描かれているが、実際には中心位置から全周囲方向に多数の基板１６が配列されるようにして保持される。また、上記蒸着流１４の基板１６表面への入射角α（実際は基板１６の法線と鉛直方向のなす角度；以下同じ）は特に限定されるものではないが、平均値で４５°～６５°程度とすれば、複屈折量（常光に対する屈折率n_oと異常光に対する屈折率n_eの差Δｎ）を大きい値としつつ蒸着膜の白濁化を防止することが可能である。

【００１１】なお、上記実施形態では、誘電体材料としてTiO_2およびSiO_2を用いているが、本発明で用いられる誘電体材料としては、基本的には使用する光に対して透明であり、かつその材料の組み合わせにより所望の複屈折量が得られればよく、例えば，Ta_2O_5、Al_2O_3、WO_3、Y_2O_3、Bi_2O_3、Nb_2O_5、ZnS、MoO_3、CeO_2、SiO、SnO_2等の金属酸化物を用いることができる。また、蒸着膜の厚みとしては上記実施例のものに限られるものではなく、種々の厚さとすることが可能であるが、各層について柱状組織が十分に成長することができる程度の厚みとすることが望ましく、例えば数十nm 以上とすることが望ましい。

【００１２】また、３種類以上の単層膜を順に繰り返し積層させるようにすることも可能である。また、１つの複屈折板１６においては、各蒸着膜３、４、５、６における光学軸も略そろえられており、この複屈折板１６を使用する際に、この光学軸の方向と光入射面の角度関係および入射角θの値を適切に調整することにより、所望の偏光透過率、偏光反射率を得ることができ、かつ、入射光の直交する偏光成分間の位相差を所望の値とすることができる光学系を得ることが可能である。

【００１３】

【実施例】以下、具体的な実施例について説明する。

【００１４】<実施例１>蒸着流１４の基板１６への入射角αを６０°に設定し、膜厚がλ／４（λ=650nm）に設定されたTiO_2とSiO_2の交互層を可視光に対して透明なガラス基板２上に２２層積層し、偏光ビームスプリッタ２０を形成した。次に、この偏光ビームスプリッタ２０の成膜表面に対し、光ビームの入射角度θが４５°となるように、かつ、光入射面と光学軸が平行となるように光ビームを入射させた（図３（Ａ））．なお、図３（Ａ）の右図は、図３（Ａ）の左図の矢印A方向から見たときの側面図である。このときのP成分の光透過率Tpと S成分の光透過率Ts の分光特性を図３（Ｂ）に示す。

【００１５】<実施例２>上記実施例１と同様にして形成された偏光ビームスプリッタ２０の成膜表面に対し、光ビームの入射角度θが４５°となるように、かつ、光入射面と光学軸が直交するように光ビームを入射させた（図4（Ａ））．なお、図4（Ａ）の右図は、図4（Ａ）の左図の矢印A方向から見たときの側面図である．このときのP成分の光透過率TpとＳ成分の光透過率Ts の分光特性を図4（Ｂ）に示す．

【００１６】<実施例３>上記実施例１と同様にして形成された偏光ビームスプリッタ２０の成膜表面に対し、光ビームの入射角度θが０°となるように光ビームを入射させた（図5（Ａ））．なお、図5（Ａ）の右図は、図5（Ａ）の左図の矢印A方向から見たときの側面図である。このときの常光の方向での偏光透過率Toと異常光の方向での偏光透過率Teの分光特性を図５（Ｂ）に示す。また、このときの常光の方向での反射位相δoと異常光の方向での反射位相δeの値を図6（Ｂ）に示す。なお、図6（Ａ）に示す光学素子配置、および図6（Ｂ）のToとTe の分光特性を示すグラフは、各々図５（Ａ）に示す光学素子配置、および図５（Ｂ）のToとTe の分光特性を示すグラフと実質的に略同じである。また、図7は上記２つの反射位相δo, δeの差の波長依存性を示すグラフである。

【００１７】<比較例>蒸着流１４の基板１６への入射角αを０°に設定し、膜厚がλ／４（λ=650nm）に設定されたTiO_2とSiO_2の交互層を可視光に対して透明なガラス基板２上に２２層積層し、複屈折性を有しないビームスプリッタ２０Ａを形成した。このビームスプリッタ２０Ａの成膜表面に対し、光ビームの入射角度θが４５°となるように光ビームを入射させた（図８（Ａ））．なお、図８（Ａ）の右図は、図８（Ａ）の左図の矢印A方向から見たときの側面図である。このときのP成分の光透過率TpとＳ成分の光透過率Ts の分光特性を図８（Ｂ）に示す。

【００１８】上記実施例１と実施例２のものを比較例のものと比較して見ると、それらの分光特性を示すグラフからも明らかなようにTpとTs の立ち上がり波長の間隔が狭くなっている。また、複屈折性を有しないものでは入射角θ=0°とした場合には偏光特性を有しないことから、これと比べて実施例3のものが大きく異なっているのが明らかである。

【００１９】なお、図6および図7においては反射の位相δo, δe に関する数値を示しているが、もちろん透過の位相も同様にして示すことが可能（図１０参照）であり、これにより、光学系の設計の自由度が大きくなる。さらに、入射角θが０°以外となる場合には、P成分の位相δpおよびS成分の位相δsをも考慮に入れて光学系の設計を行うことができる。

【００２０】<実施例4>蒸着流１４の基板１６への入射角αを６０°に設定し、膜厚が下記表１の如く設定されたTiO_2（複屈折量Δn=0.075）とTa_2O_5（複屈折量Δn=0.065）の交互層を、可視光に対して透明なガラス基板２上に３５層積層し、さらに膜厚が下記表１の如く設定されたSiO_2（複屈折量Δn≒0）よりなる最上層を形成して位相板２０Ｂを作製した。このときの全膜厚は

2.064nm であった。この位相板20Bを図9（A）に示す如く配置し、波長λoが600nm の光ビームをこの位相板20Bの成膜表面に対して入射角θが0°となるように光ビームを入射させた（図9（A））。なお、図9（A）の右図は、図9（A）の左図の矢印A方向から見た時の側面図である。

【0021】このような状態に配設された位相板20Bは、波長λo が600nm の光ビームに対し、直交する偏光成分の位相を互いに88°ずらすことができ、λ／4板として機能する。このときの常光の方向での偏光透過率Toと異常光の方向での偏光透過率Teの分光特性を図9（B）に示す。また、このときの常光の方向での透過位相δo と異常光の方向での透過位相δe の差の波長依存性を表すグラフを図10に示す。下記表1に、本実施例の具体的な膜構成を示す。

【0022】

【表1】

膜No.	材料	屈折率no	膜厚d (nm)	4nod/λo
	空気	1.0		
1	SiO_2	1.46	89.5	1.045
2	TiO_2	2.3	39.5	0.727
3	Ta_2O_5	2.0	50.0	0.800
4	TiO_2	2.3	48.9	0.900
5	Ta_2O_5	2.0	62.5	1.000
6	TiO_2	2.3	54.3	1.000
7	Ta_2O_5	2.0	62.5	1.000
8	TiO_2	2.3	54.3	1.000
9	Ta_2O_5	2.0	62.5	1.000
10	TiO_2	2.3	54.3	1.000
11	Ta_2O_5	2.0	62.5	1.000
12	TiO_2	2.3	54.3	1.000
13	Ta_2O_5	2.0	62.5	1.000
14	TiO_2	2.3	54.3	1.000
15	Ta_2O_5	2.0	62.5	1.000
16	TiO_2	2.3	54.3	1.000
17	Ta_2O_5	2.0	62.5	1.000
18	TiO_2	2.3	54.3	1.000
19	Ta_2O_5	2.0	62.5	1.000
20	TiO_2	2.3	54.3	1.000
21	Ta_2O_5	2.0	62.5	1.000
22	TiO_2	2.3	54.3	1.000
23	Ta_2O_5	2.0	62.5	1.000
24	TiO_2	2.3	54.3	1.000
25	Ta_2O_5	2.0	62.5	1.000
26	TiO_2	2.3	54.3	1.000
27	Ta_2O_5	2.0	62.5	1.000
28	TiO_2	2.3	54.3	1.000
29	Ta_2O_5	2.0	62.5	1.000
30	TiO_2	2.3	54.3	1.000
31	Ta_2O_5	2.0	62.5	1.000
32	TiO_2	2.3	54.3	1.000
33	Ta_2O_5	2.0	62.5	1.000
34	TiO_2	2.3	48.9	0.900
35	Ta_2O_5	2.0	50.0	0.800
36	TiO_2	2.3	39.5	0.727
全膜厚			約2064	
	ガラス基板（BK7）	1.51		

但し、λo=500nm

【0023】
【発明の効果】以上説明したように、本発明の複屈折板およびこれを用いた光学系によれば２種類以上の単層膜を交互に斜め蒸着せしめて、斜め蒸着膜を形成している。したがって、各単層膜を形成する誘電体材料、各単層膜の光学膜厚および層数をパラメータとして、所望の複屈折量のものを得ることができるので光学素子の設計自由度を高めることができる。また、各単層膜の光学軸の方向を略そろえておき、この光学素子を使用する際に、この光学軸の方向と光入射面との角度関係、および入射角度を適切に選択することにより光学素子ひいては光学システムの設計自由度をさらに高めることができる。

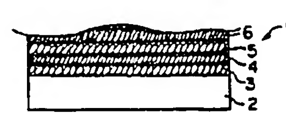
【0024】例えば、従来の偏光ビームスプリッタにおいては、小さい入射角で光ビームが入射する場合には、板状のビームスプリッタは使用できず、ガラスブロックタイプのビームスプリッタを使用しなければならなかったが、本発明のものを適用することにより、小さい入射角の光ビームに対しても板状のビームスプリッタで直交する２偏光成分を確実に分離することが可能となる。また、このビームスプリッタに位相板としての機能を持たせる設計とすることもできるので、従来ビームスプリッタにおいて、その後段の一方の光路上に設けられることがあった位相板（例えばλ／４板、λ／２板）が不用となる。

【0025】また、例えば、カラー液晶ビデオプロジェクタのダイクロイックプリズムで各々の色情報を担持した偏光成分が合成される際に、従来のものではそれら各偏光成分の分光特性で立ち上がり波長の値に大きなずれが生じているため、合成後の分光特性が階段状となってしまうが、本発明を適用することにより上記２つの偏光成分の分光特性における立ち上がりの波長の値を極めて近い値に設定することができることから、これら２つの偏光成分を合成したときに合成分光特性が階段状となるのを防止することが可能である。なお、上記２つの偏光成分のうち一方の分光特性を変えることなく、他方の分光特性を変えて、両者の間隔を拡げることも可能である。

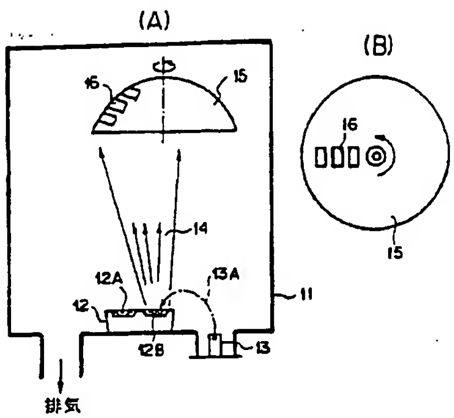
【図面の簡単な説明】
【図１】本発明の実施形態に係る複屈折板の層構成を示す概略図
【図２】図１に示す複屈折板の斜め蒸着膜を形成する蒸着装置の一例を示す概略図
【図３】実施例１の光学素子配置図（Ａ）および光透過率特性を示すグラフ（Ｂ）
【図４】実施例２の光学素子配置図（Ａ）および光透過率特性を示すグラフ（Ｂ）
【図５】実施例３の光学素子配置図（Ａ）および光透過率特性を示すグラフ（Ｂ）
【図６】実施例３の光学素子配置図（Ａ）、および光透過率特性と反射位相を示すグラフ（Ｂ）
【図７】実施例３における反射位相の差を示すグラフ
【図８】比較例の光学素子配置図（Ａ）および光透過率特性を示すグラフ（Ｂ）
【図９】実施例４の光学素子配置図（Ａ）および光透過率特性を示すグラフ（Ｂ）
【図１０】実施例４における透過位相の差を示すグラフ
【符号の説明】

１	複屈折板
２	透明ガラス基板
３、４、５、６	単層膜
１１	ベルジャー
１２	蒸発源
１２Ａ、１２Ｂ	蒸着材料
１３	電子銃
１３Ａ	電子ビーム
１４	蒸着流
１５	ドーム状ワーク
１６	基板
２０，２０Ａ	ビームスプリッタ
２０Ｂ	位相板

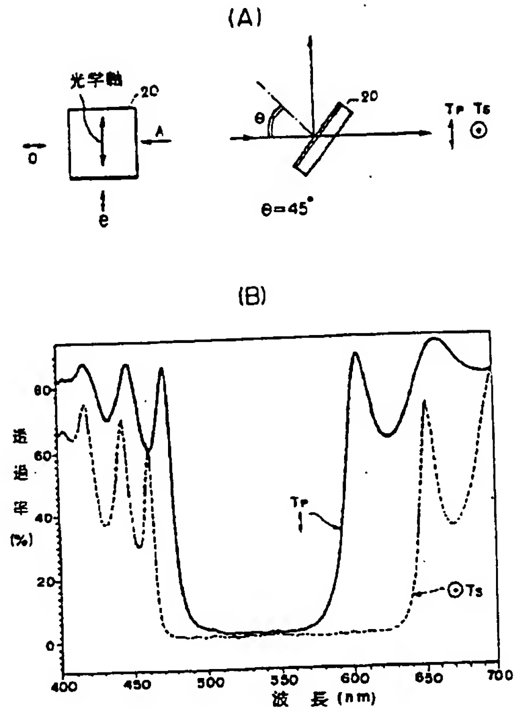
【図１】



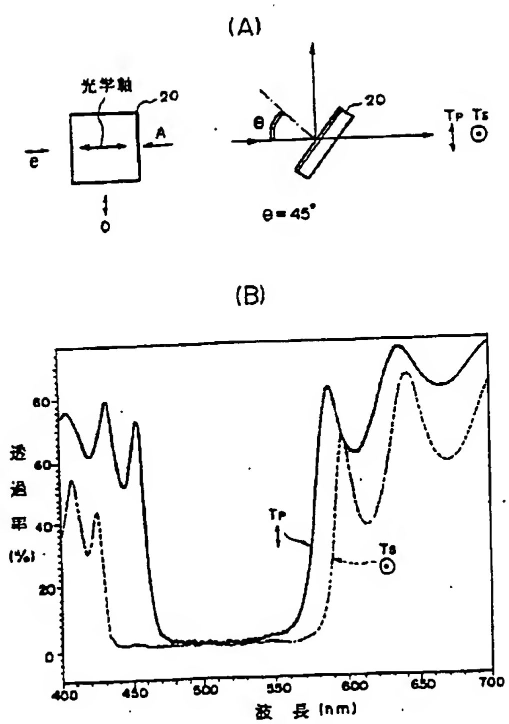
【図2】


(A)
(B)
16
15
14
12A
13A
12
12B
13
11
排気

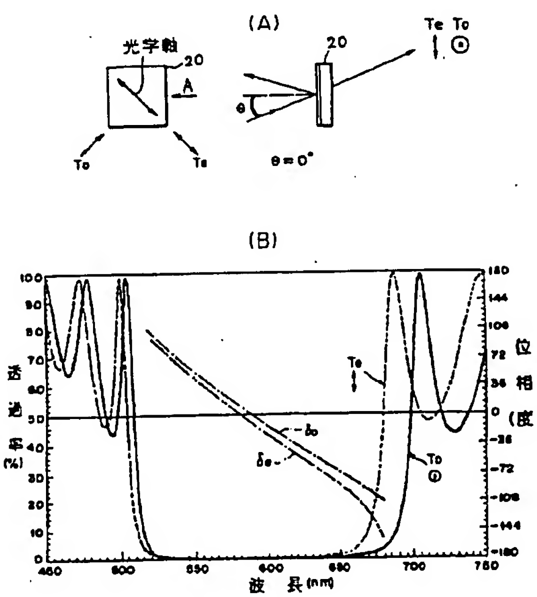
【図3】


(A)
光学軸
20
A
o
e
θ
Tp Ts
θ=45°
(B)
透過率(%)
Tp
Ts
波長(nm)

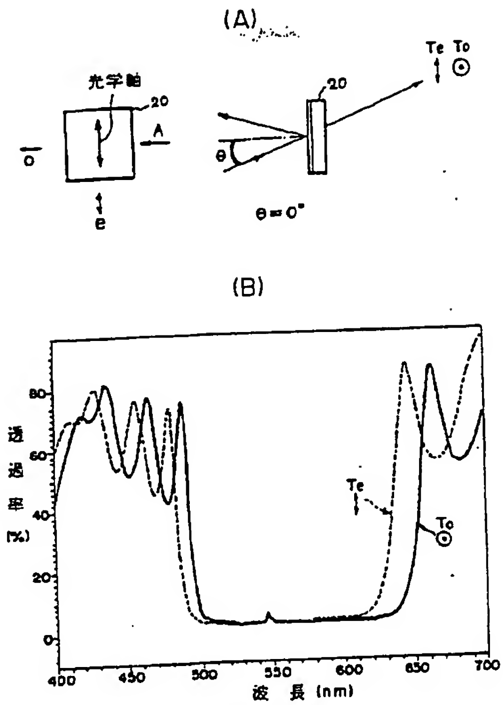
【図4】


(A)
光学軸
20
A
e
o
θ
Tp Ts
θ=45°
(B)
透過率(%)
Tp
Ts
波長(nm)

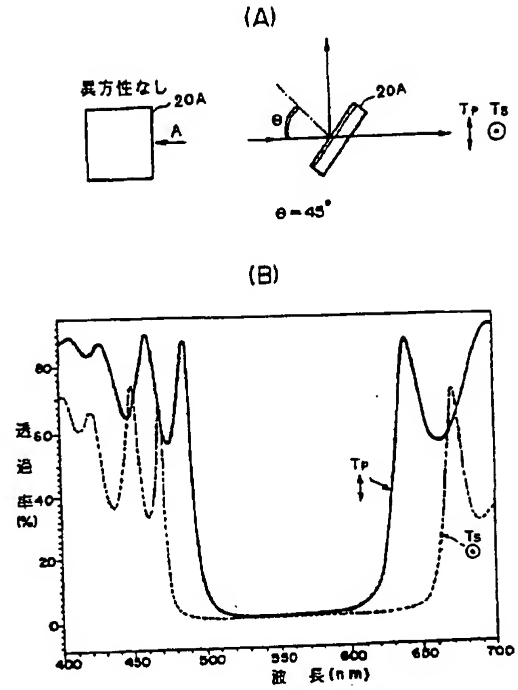
【図6】


(A)
光学軸
20
A
To
Te
θ
Te To
θ=0°
(B)
透過率(%)
位相(度)
Te
To
δo
δe
波長(nm)

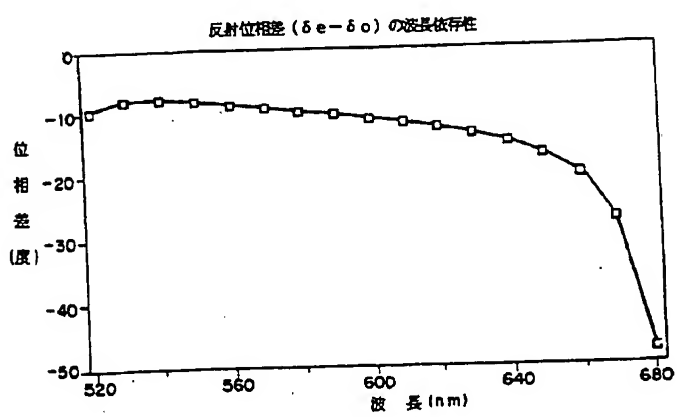
【図5】


(A)
光学軸
20
A
o
e
Te To
θ
θ=0°
(B)
透過率(%)
80
60
40
20
0
400
450
500
550
600
650
700
波長(nm)
Te
To

【図8】

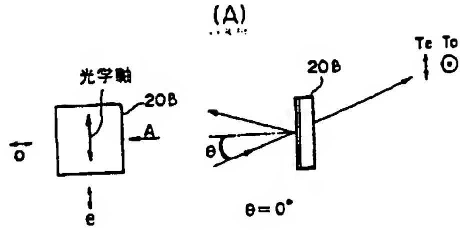

(A)
異方性なし
20A
A
θ
Tp Ts
θ=45°
(B)
透過率(%)
80
60
40
20
0
400
450
500
550
600
650
700
波長(nm)
Tp
Ts

【図7】

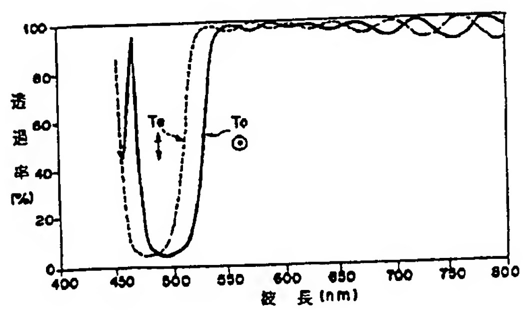

反射位相差（δe－δo）の波長依存性
位相差(度)
0
-10
-20
-30
-40
-50
520
560
600
640
680
波長(nm)

【図9】

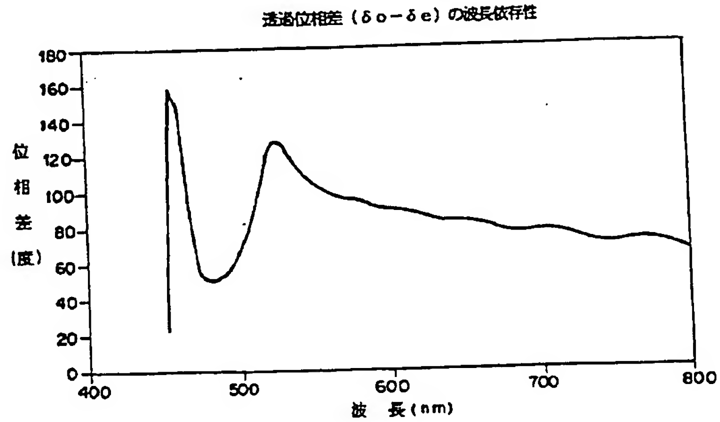
(A)



(B)



【図10】



【手続補正書】

【提出日】平成8年1月30日

【手続補正1】

【補正対象書類名】明細書

【補正対象項目名】0022

【補正方法】変更

【補正内容】

【0022】

【表1】

膜No.	材料	屈折率no	膜厚d(nm)	4nod/λo
	空気	1.0		
1	SiO_2	1.46	89.5	1.045
2	TiO_2	2.3	39.5	0.727
3	Ta_2O_5	2.0	50.0	0.800
4	TiO_2	2.3	48.9	0.900
5	Ta_2O_5	2.0	62.5	1.000
6	TiO_2	2.3	54.3	1.000
7	Ta_2O_5	2.0	62.5	1.000
8	TiO_2	2.3	54.3	1.000
9	Ta_2O_5	2.0	62.5	1.000
10	TiO_2	2.3	54.3	1.000
11	Ta_2O_5	2.0	62.5	1.000
12	TiO_2	2.3	54.3	1.000
13	Ta_2O_5	2.0	62.5	1.000
14	TiO_2	2.3	54.3	1.000
15	Ta_2O_5	2.0	62.5	1.000
16	TiO_2	2.3	54.3	1.000
17	Ta_2O_5	2.0	62.5	1.000
18	TiO_2	2.3	54.3	1.000
19	Ta_2O_5	2.0	62.5	1.000
20	TiO_2	2.3	54.3	1.000
21	Ta_2O_5	2.0	62.5	1.000
22	TiO_2	2.3	54.3	1.000
23	Ta_2O_5	2.0	62.5	1.000
24	TiO_2	2.3	54.3	1.000
25	Ta_2O_5	2.0	62.5	1.000
26	TiO_2	2.3	54.3	1.000
27	Ta_2O_5	2.0	62.5	1.000
28	TiO_2	2.3	54.3	1.000
29	Ta_2O_5	2.0	62.5	1.000
30	TiO_2	2.3	54.3	1.000
31	Ta_2O_5	2.0	62.5	1.000
32	TiO_2	2.3	54.3	1.000
33	Ta_2O_5	2.0	62.5	1.000
34	TiO_2	2.3	48.9	0.900
35	Ta_2O_5	2.0	50.0	0.800
36	TiO_2	2.3	39.5	0.727
全膜厚			約2064	
	ガラス基板 (BK7)	1.51		

但し、λo=500nm

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